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FIELD EXPOSURE OF CHEMICAL SCHOOL STUDENTS AND CADRE TO FOG OIL AND HEXACHLOROETHANE (HC) SMOKES

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Laboratory studies continue to reveal potentially toxic effects of substances generated by the normal use of military weapon and equipment systems. These are the sources of occupational health exposure to the soldiers. Two of the airborne contaminants routinely used in military training are fog oil and hexachloroethane smokes. This study was initiated to evaluate the extent of soldiers' exposure to smokes specifically during training at the U.S. Army Chemical School. Both personal sampling and general area background air samping were conducted during the three training courses, all of which involve smoke use. These three courses are: Field Training Exercise, and Operate and Maintain training (one for officers and one for enlisted military). Overexposures to fog oil smoke were encountered in the 54B10 advanced individual training. Students in the basic noncommissioned officer's course and chemical officer's basic courses received exposures lower than the 54B10 students. Exposures to fog oil smoke among the three groups of students
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during the field training exercise were not found to be statistically different. Neither the instructors nor the students received exposure in excess to the threshold limit value for zinc chloride during training with hexachloroethane smoke. Some attempts have been made to explain the difference in the exposure level. Controls should be instituted to minimize exposure of soldiers to smoke wherever possible. The wearing of a protective mask during smoke training is encouraged.

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EXECUTIVE SUMMARY

Laboratory studies at the U.S. Army Biomedical Research and Development Laboratory (USABRDL) continue to reveal the toxic effects of potentially harmful substances generated by the normal use of military weapon/equipment systems. Many of these potentially harmful substances are the sources of occupational exposure to the soldiers. One of the airborne contaminants routinely encountered in military training is smoke. U.S. Army doctrine recognizes the importance of deliberately-generated smoke on the battlefield and emphasizes the need to use smoke such as fog oil and hexachloroethane (HC) in the training environment. The toxicity of fog oil has been studied, and results indicate adverse pulmonary changes and toxic effects in rats. Incidents have occurred in which human incapacitation has resulted from exposure to HC smoke. Studies to measure soldiers' exposure to fog oil and HC smokes had not been conducted prior to this effort.

This study was initiated to evaluate the extent of soldiers' exposure to smoke during training at the U.S. Army Chemical School (USACMLSCH). In the absence of an exposure standard for fog oil, the threshold limit value (TLV) for mineral oil mist (a substance considered similar to fog oil) was used as a standard to which personnel exposures to fog oil smoke could be compared. Exposures to HC smoke were compared to the TLV for zinc chloride ($ZnCl_2$), the most abundant component and a significant toxicant, in HC smoke. Results of fog oil smoke exposure sampling indicated that potential overexposure occurs among students qualifying for the military occupational specialty (MOS), "Chemical Operations Specialist" (54B10). Potential overexposures to fog oil smoke were found in both training scenarios in which students either learned to "operate and maintain" (O&M) the M3A4 Pulse Jet Mechanical Smoke Generator or underwent field training exercises (FTX). In general, higher exposures were experienced during the O&M training scenario; and lower exposures were received during the FTX scenario. The 54B10 students received significantly higher exposure, during O&M training than the students in either the Chemical Officers' Basic Course (COBC) or the Basic Non-commissioned Officers' Course for Reclassified Non-commissioned Officers (BNCOC/R). Exposures during the FTX scenario in the three courses were not found to be significantly different. There were no overall differences between students and cadre in their exposures to fog oil smoke during the O&M training scenario. Neither the cadre nor the students received excessive exposures to $ZnCl_2$ during training in the employ and ignite (E&I) demonstration using HC smoke pots.

Potential overexposure to fog oil smoke was demonstrated by the sampling results. Excessive exposure was attributed to the generators being placed in close proximity, 10 feet to one another; to cadre and students consistently staying close to their generators; and to an overly vigorous training tempo. The numbers of generators used in each training scenario did not appear to affect the magnitude of personnel exposure to fog oil smoke.

The particle-size distribution of fog oil smoke was studied. Particle-size mass median aerodynamic diameters (MMAD) fell between 1 and 3 micrometers (μm), well within the range of maximum retention of the particles in the alveolar region of the lung.

Both the students and the cadre should be cautioned of the exposure to fog oil smoke. Overexposure can be minimized by modifying work habits, keeping the soldiers informed of the exposure risk, and greater physical separation of smoke generators. Use of the standard issue protective mask is encouraged.

DEDICATION

In dedication to the late Dr. Thomas Anthony Miller, former Chief of the Health Effects Research Division of the U.S. Army Biomedical Research and Development Laboratory. His continued support of this research program provided the impetus and committed the resources needed to ensure the success of this project. The authors are thankful for his interest in the occupational health exposure assessment program, and in the protection of the health and safety of the soldiers in the field.

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The authors wish to thank the staff officers at the Smoke Division, the instructors, and particularly the students at the U.S. Army Chemical School for their generous cooperation, without which it would have been impossible to complete this research. Special thanks go to MAJ James Verney, who showed tremendous interest in our work and was supportive in every way and to MAJ Edward Byde, who was equally supportive, for his untiring efforts to meet our ever-present need for assistance at Fort McClellan during our field sampling. We hope that this work will benefit the soldiers in the field.

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1.0 INTRODUCTION

1.1 RESEARCH OBJECTIVES

The principal objectives for exposure assessment in military occupational health research are to characterize the potential hazards and to evaluate the extent of personnel exposures to airborne contaminants.

1.2 SCOPE OF THE STUDY

An evaluation of the soldiers' exposure to fog oil and HC smokes at the U.S. Army Chemical School (USACMLSCH) is the first step of the smoke exposure research plan (Smart, 1989), at the U.S. Army Biomedical Research and Development Laboratory (USABRDL) for assessing military occupational exposures to smoke. Field sampling for personnel exposures to fog oil smoke was performed under two different training scenarios during three separate courses given at the USACMLSCH. The differences in personnel exposure to fog oil smoke among the training courses, between the two training scenarios, and between cadre and students, were studied. Soldiers' exposure to HC smoke was also evaluated in one training situation.

1.3 BACKGROUND

A literature search was made to gather existing information on personnel exposure tc fog oil and HC smokes and on methods of sampling and analysis of the airborne smoke materials. There have been no studies that measured soldier exposure to fog oil or HC smoke. Studies have been performed to evaluate the adequacy of experiments to establish a relationship between fog oil obscuration and concentration in order to estimate dosage (Policastro and Dunn, 1985). Additional studies have been performed to validate mathematical dispersion models through measurements of total particulate concentration and particle-size distribution (Liljegren et al., 1986b). While these studies will be useful for predicting the probability of exposure at a given distance from a fog oil or HC source, they do not have the ability to correlate soldier work patterns (principally affecting the magnitude and the duration of exposure) with smoke plume fluctuations.

Menichini (1986a) described sampling and analytical methods for oil mist (lubricating oils, mineral oils, and other metal-working lubricants) for use in industrial environments. Because of the similarities between these oils and fog oil, procedures should be equivalent. Samples taken at a number of work places with oil mist exposures ranged from a mean of 3 milligrams (mg) of contaminant per cubic meter of air (mg/m^3) to 8 mg/m^3 for samples taken from 30 min to 3 hours. Menichini (1986b) also described procedures for determining particle-size distribution of oil mist and aerosols in several work places. Particulate sizes ranged from 1.0 to 11.0 μm, with the largest percentage of particles below 5 μm (mist concentration 0.1 to 1.3 mg/m^3).

1.4 EXPOSURE SCENARIOS AND TRAINING COURSES

The two training scenarios in which soldiers could be exposed to fog oil smoke are the "operate and maintain" (O&M) and the field training exercise (FTX). In the O&M scenario, students learned to operate and maintain the M3A4 Pulsed Jet Mechanical Smoke Generator (Figure 1). Hands-on training was received by the students, and both the cadre and the students located themselves close to the generators. Subsequent to the O&M training, the students were sent out to the field during the FTX scenario to operate the generators independently. They were given several missions over a period of several days, to generate smoke to cover a designated objective. Cadre remained away from the smoke and observed the students FTX training activities. The three training courses and the training requirements associated with the two training scenarios are discussed below. A training session involving the use of HC smoke pots or grenades was held during the O&M, to demonstrate to the students on how to "employ and ignite" (E&I) HC smoke. The E&I demonstration was only given to the 54B10 students and is also explained below.

1.4.1 Chemical Officers' Basic Course (COBC)

Smoke training in the COBC involves 15 hours of practical O&M training to learn how to operate and maintain the M3A4 Smoke Generator, and a 38.5-hour FTX with 5 to 8 missions. The O&M training scenario was scheduled for 4 hours per day in 2 consecutive days. Operating and maintenance procedures were practiced by the students while the generators were producing smoke. Smoke was continuously produced in several 1-hour segments of the 2 consecutive days. Up to five segments of smoke generation were carried out within those 2 days. Our results of field sampling reflected exposure during one such training segment (Tables 5-9). Upon completion of the O&M training, trainees were prepared for the FTX. In the 38.5-hour FTX, students were given smoke missions; they worked independently while the cadre observed and evaluated their performance. The students generated smoke in various scenarios to obscure a river crossing, a drop zone, or a brigade support area, or to screen the flank of a troop movement. Each of these FTX missions usually lasted 1 hour. There were 20-50 students in each course, and as many as eight courses have been offered per year. Cadre are on station at the USACMLSCH for one 36-month assignment during their entire career. The optimum cadre-generator-student ratio was 1:2:4; however, the most common ratio has been 1:4:8. Four support personnel circulated in the training area, but they normally received no smoke exposure.

1.4.2 54B10 Advanced Individual Training (AIT)

The AIT for soldiers qualifying for the military occupational specialty (MOS) 54B10, Chemical Operations Specialist, involved 9 hours in O&M training on the M3A4 generator and 48 hours of the FTX, during which five to eight missions were usually performed. Training requirements for the MOS 54B10 were identical to those given in the COBC. However, the actual training appeared to be more intensive. About 2,400 trainees, in class sizes ranging between 30 and 35 in each course, have been trained annually. Cadre-generator-student ratios were the same as described in the COBC. An

additional requirement for this course was the 1-hour E&I demonstration exercise, in which the use of HC smoke pots was taught, and the application of HC smoke was demonstrated. During this exercise, one instructor would ignite an M8 smoke grenade, while the students stayed about 50 feet upwind from the source of smoke. The M5 series smoke pots and the M8 grenades normally were used although, in some cases, M18 colored smoke grenades may be substituted for the smoke pots.

1.4.3 Basic Non-commissioned Officers' Course for Reclassified Non-commissioned Officers (BNCOC/R)

The BNCOC/R course was designed for training non-commissioned officers (NCO) who recently have transferred from another MOS into the chemical field. The course closely resembled the 54B10 AIT course. Class sizes for the NCO course ranged from 35 to 42 per class; and 26 courses have been offered by the USACMLSCH each year. The NCO students spent 9 hours in O&M training and 27 hours in the FTX. The subject matter in smoke training was identical to that offered in the COBC.

2.0 MATERIALS AND METHODS

2.1 Fog Oil Smoke Field Sampling

2.1.1 Personnel Breathing Zone Sampling

The original intent was to collect both the aerosol and vapor phases of the fog oil smoke. Various collection media and methods were investigated for the field sampling. Katz et al. (1980) characterized the chemical and physical composition of fog oil smoke and found that fog oil was vaporized and forced out of the generator, and aerosolized smoke in the form of condensate was immediately formed. The condensate consisted mainly of microdroplets of oil, which could remain afloat for about an hour (Katz et al., 1980). Past research experiences at USABRDL were successful in the use of 37-millimeter (mm) Grade AAA binderless glass fiber filters to collect fog oil smoke aerosol (Liljegren et al., 1986b). Field sampling for the vapor-phase was contemplated, but was not considered to be important, since previous research on fog oil smoke dispersion had indicated that the vapor phase constituted less than 1 percent of the total amount of smoke (Liljegren et al., 1986a).

Two days of preparation were required prior to the actual sampling. Forty Gilian Dual High Flow Pumps (DHFS-113A) were electrically charged for 16 hours and then calibrated with an electronic primary standard (Gilian Buck Calibrator^{R} and the Gilibrator^{R}). The flow rates of the Gilian DHFS-113A pumps with the cassette/tubing assemblies were adjusted to 3.5 $\pm$ 0.2 liters per min (Lpm). Seven flow readings were made for each pump to arrive at an average calibrated flow rate.

Thirty of the air sampling pumps equipped with cassette filters and hose were fitted onto the modified load-carrying equipment (LCE) (Figure 2). These LCE had been adapted to contain personnel breathing zone sampling equipment. Pumps, tubing, and collection media were wrapped in pockets and straps to minimize interference with the activities of the people wearing the LCE. The remaining pumps were used for general area sampling and as backups.

Exposure concentrations of interest were those levels greater than half of the TLV for mineral oil mist (5 mg/m^3). The flow rate of 3.5 Lpm for 60 min (as an average period of exposure) would allow the collection of greater than the detection limit of 0.5 mg per filter (Rosencrance et al., 1988). This is equivalent roughly to 2.5 mg/m^3.

The flow rates of the air sampling pumps were checked for calibration immediately after field sampling to verify consistent pump performance. All pumps were found to stay within $\pm$ 0.2 Lpm (<5 percent of adjusted flow rate) from the original calibrated flow rates. Ambient temperatures between flow rate calibration and field sampling varied as much as 40 degrees Fahrenheit (^{O}F). Sample volume adjustments based on Charles' Law were made to correct the temperature variations. The following equation was used for the sample volume adjustment:

$$V_{corrected} = V_{calib} * (T_{sampling}/T_{calib})$$

Where $V_{corrected}$ is the corrected sample volume for use in concentration calculations, V_{calib} is the sample volume based on temperature at calibration. $T_{sampling}$ is the recorded ambient temperature during field sampling, expressed in Rankine ($^{o}F + 460$), and T_{calib} is the recorded ambient Rankine temperature during calibration ($^{o}F + 460$).

One liter of bulk fog oil sample was also collected during each sampling event and submitted to the laboratory for analysis. The laboratory used the bulk samples to verify the analyte in the collected filters.

2.1.2 General Area Sampling

General area sampling also was performed to supplement the breathing zone sampling. A diagram of the general area sampling stand is shown in Figure 3. This included aerosol-phase fog oil smoke collection and cascade impactor particle-size distribution sampling. Three general area stands were set up in the training area. One stand was located 50 feet upwind of the generator line, the second on the generator line, and the third at 50 feet downwind. All three stands contained identical sampling equipment. The same sampling train was used as previously described for breathing zone sampling. An INTOX^{R} seven-stage cascade impactor collected particle samples at discrete cutoff diameters ranging from 0.1 to 11 μm.

2.2 HC Smoke Field Sampling

Katz et al. (1980) defined the ideal HC mixture chemical reaction in the following stoichiometric equation:

$$2Al + C_2Cl_6 + 3ZnO \rightarrow 3ZnCl_2 + AL_2O_3 + 2C + Heat$$

Zinc chloride ($ZnCl_2$) leaves the reaction zone as a hot vapor in the burning HC smoke pot, and on cooling below the condensation point, forms the desired aerosol. Hence, $ZnCl_2$ is the target substance to sample in HC smoke. Zinc chloride sampling entailed the use of mixed cellulose ester filters connected to a DHFS-113A high flow pump calibrated at 3.5 Lpm, as described above. The sampling train was loaded onto the LCE for personnel sampling.

For general area sampling, the sampling train was of the type used for the breathing zone sampling. Cascade impactors were employed for determining the particle-size distribution of the $ZnCl_2$ in the smoke. Three general area stands were set up in the training area; their locations were similar to those for fog oil smoke sampling.

2.3 Human Use Protocol

A plan for use of human volunteers to participate in the personnel air sampling was developed for this study and submitted to the U.S. Army Medical Research and Development Command (USAMRDC) Human Subjects Research

Review Board for review and approval. The intent is to comply with the requirements of Title 45 Code of Federal Regulations, Part 46; Department of Defense Directive 3216.2; Army Regulation 70-25 and USAMRDC Regulation 70-25. The plan was approved by the HSRRB.

Before each field sampling event, students and cadre were briefed on the nature, duration, and purpose of this research; the methods and means by which samples would be collected and analyzed; and the implications of their voluntary participation. The sampling equipment was available for their inspection. They were given an opportunity to ask questions and were provided with names and addresses of both technical and legal advisors. Those who agreed to volunteer filled out and signed a DA Form 5303-R, Volunteer Agreement Affidavit, consenting to participate. Only those students who had completed and signed the forms were used in the study.

2.4 Fog Oil Smoke Analyses

2.4.1 Sample Preparation

Immediately after sampling, each glass fiber filter was carefully removed from its plastic cassette and transferred into a 13 x 100 mm glass screw-cap culture tube. This was done to avoid potential sample loss by evaporation or sample migration in the cassette. In the laboratory, 3 milliliters (mL) of methylene chloride was added to each tube to extract the collected fog oil aerosol from the filter. Then the contents were shaken on a vortex mixer for 30 seconds. By mixing for such a short time, we extracted the oil without disintegrating the glass fiber filter. A 1.5-mL aliquot of the methylene chloride extract was transferred to a 2-mL gas chromatography auto-sampler vial for analysis. Operating conditions of the gas chromatograph are described in Table 1, page 34.

In addition to the glass fiber filters, fog oil samples on round glass slides from the cascade impactors were processed. Initially, the glass slides were received in the laboratory in small round metal containers. This sample storage method made it difficult to obtain good sample recoveries because the slides came into contact with the sides of the containers. The containers were small and wide, making recovery of any sample that came into contact with the container sides difficult. This problem was solved by placing the entire metal container in a 30-mL wide-mouth vial with a teflon cap. Then 3 mL of methylene chloride was added and the vial was mixed on a vortex mixer for one min to remove the fog oil not only from the slide but from the inside of the metal storage container. Samples then were transferred to auto-sampler vials for analysis. Later, glass slide samples were placed in the 30-mL glass vials directly while in the field, and the use of the metal containers was eliminated.

A sample recovery study was carried out to determine the efficiency of the extraction techniques and the stability of fog oil samples during storage. In the laboratory, a series of glass fiber filters were spiked with fog oil and placed in plastic air sampling cassettes to simulate samples collected in the field. A series of glass slides was also spiked and placed in the metal containers to simulate the first set collected in the

field. A total of 30 glass fiber filters and 30 glass slides was spiked. Spiked samples were grouped into two ranges, a low range that included spike weights of 1.8 mg to 5.8 mg and a high range of 10.6 mg to 25.3 mg. A set of five low range and five high range spiked samples for both the glass fiber filters and glass slides was analyzed immediately and at 3 and 6-month intervals. Results of the sample recovery are presented on Table 2, page 34.

Standards were prepared by weighing milligram quantities of fog oil into 100-mL volumetric flasks. These then were diluted to volume with methylene chloride. Standards were prepared in the range of 400 mg/liter to 10,000 mg/liter.

2.4.2 Instrument Conditions

Fog oil samples contain hundreds of organic compounds; when analyzed by capillary gas chromatography, the chromatograms display hundreds of peaks and require run times of up to 1 hour. Since we were interested only in overall fog oil concentration and rapid sample turnaround, we employed a 5-meter, 0.53-mm methyl silicone capillary column (Hewlett-Packard Co., Avondale, PA). The gas chromatograph oven temperature was held at 190 degrees Celsius (^{o}C) for 1 min. The temperature was raised at a rate of 35 ^{o}C per min to 300 ^{o}C and maintained for 2 min. A packed column injection port liner and column flow of 25 mL/min of helium were used. This forced the fog oil through the column quickly, resulting in a single broad peak well separated from the methylene chloride solvent peak (Figure 3). The total run time was reduced from 1 hour to 6.5 min. Electronic peak area integration gave inconsistent data owing to the slightly jagged apex of the fog oil peak. This problem was solved by using peak height measurements to construct our standard curves. All analyses were performed on a Hewlett Packard 5890A gas chromatograph equipped with a Hewlett Packard 3392A integrator, a flame ionization detector (FID) and Hewlett Packard 7672A automatic sampler.

2.5 HC Smoke Sample Analysis for Zinc

2.5.1 Sample Preparation

The analytical laboratory received HC samples in filter cassettes from general area and personnel sampling. Cascade impactor samples had been transferred into small round metal containers, with one impaction stage (glass slide) per container. The top surface of each glass slide had been coated with a thin film of silicone oil in hexane prior to sample collection. The silicone did not interfere with the detection of zinc (Zn) by atomic absorption spectroscopy (AA).

Since each of the glass cascade impactor slides was agitated during shipment to the laboratory, it was important to extract all of the Zn from the walls of the container as well as the slide itself. Each slide and its metal container was extracted three times with 3 mL of a 10 percent nitric acid solution into a 10-mL glass volumetric flask. The volume in the flask was adjusted to the meniscus with 10 percent nitric acid.

An unused empty container was extracted three times with 3 mL of 10 percent nitric acid. The three extracts were transferred to a 10 mL volumetric flask, and the volume was adjusted to 10 mL with 10 percent nitric acid. This served as the sample blank.

It was necessary to analyze an empty container for Zn because the container is made of metal. Analysis of extractions made from an empty metal container showed positive values for Zn, indicating that trace amounts of Zn existed in the metal containers.

Aliquots of a 1,000 parts per million (ppm) reference stock solution (Fisher Scientific Co., Fairlawn, NJ.) were diluted with reagent grade water (18 megaohms/cm resistance) to provide Zn standards. Concentrations ranged from 0.050 milligram per liter (mg/L) to 1.000 mg/L.

2.5.2 Instrument Conditions

Solutions were analyzed for Zn on a Perkin-Elmer model 3030 atomic absorption spectrophotometer (Perkin-Elmer Corp., Norwalk, CT) with a hollow cathode lamp for Zn determination. The spectrophotometer wavelength was set at 213.9 nanometers (nm) with a slit width of 0.7 nm. A lean blue, air/acetylene flame was used to atomize the standards and samples. The conditions are described on Table 3, page 35. The detection limit for Zn was 0.050 mg/L.

2.5.3 Calculations

Peak areas for working standards were plotted against their concentrations to obtain a standard curve. The peak area of the sample unknown and sample blank were compared to the standard curve to obtain a concentration in mg/L. Next, the sample blank's concentration (mg/L) was subtracted from the sample unknown concentration (mg/L) and the difference converted to mg/10 mL to obtain a concentration of mg (Zn)/glass slide. Each sample extract containing a concentration in excess of 1 mg/L was diluted with reagent grade water to obtain a sample concentration within the upper and lower limits of the standard curve.

The accuracy of the extraction method was tested by conducting recovery studies on small metal containers spiked with the two Zn standards (Table 4, page 35). The percent recovery ranged from 97.8 to 100.60 percent for the low level (1 mg/L) accuracy spike and from 95.60 to 99.80 percent for the high level (10 mg/L) accuracy spike.

3.0 STATISTICAL METHODS

Statistical analyses of personal and general area concentrations of fog oil were conducted with one way analysis of variance (ANOVA) to determine statistical effects. The ANOVA was used to test for the main effects of differences among the three courses: 54B10 AIT, COBC, and BNCOC; for the main effects of differences between the O&M and the FTX training scenarios; and for an overall effect between students and cadre in the fog oil exposure concentrations received in the O&M training scenario. Data were analyzed by course to determine any difference between student and cadre, among courses, and between scenarios. The variance ratio test (F-test) provided in the ANOVA was used to test for the difference between two means; the Scheffe multiple comparison procedure was used for comparisons among three or more means. The one-tailed Student's t-test was used to compare the concentration levels of personnel exposure to fog oil smoke against a TLV. SAS® PROC GLM (General Linear Models Procedure) commercial computer software was used for analyses. Results are reported as mean mg/m^3-hour $\pm$SE.

HC concentrations are reported as mean mg/m^3-min $\pm$SD, (n = 3).

4.0 RESULTS

Airborne concentration levels of fog oil smoke adjusted to a 1-hour period of exposure are tabulated in Table 5 below.

TABLE 5
Summary of Fog Oil Smoke Sample Results in mg/m³
Based on One-Hour Exposure

O&M			FTX		
54B10AIT	BNCOC	COBC	54B10AIT	BNCOC	COBC
680.19	244.82	122.54+	35.09	23.55	29.94
315.50	228.73+	103.11+	31.69	21.78	10.68
281.68	202.14	90.30	29.73	14.28	8.84
231.51	156.36	71.50	29.41	7.00	8.70
219.39	151.06	71.45	28.62	5.95	8.12
186.71+	132.14	64.96	26.07	4.17	7.73
185.85	109.87+	57.16+	24.11	3.89	7.66
178.87	108.51	46.92	19.84	0.00	7.39
176.77	108.43	37.28	19.63	0.00	7.00
114.59	77.58	28.29	16.46	0.00	6.30
108.23	73.71	27.45+	16.43	0.00	6.28
107.22	72.08	22.82+	15.56	0.00	6.25
99.82+	69.72+	19.28	15.45		3.73
93.71	69.42+	14.66	14.45	*	0.00
86.54+	62.14+	13.95	14.10		0.00
61.31+	44.90+	11.71	11.32		0.00
52.97	43.18	9.34	10.56		0.00
45.74	42.15+	7.98	10.04		0.00
38.02	39.57+	5.53	6.10		0.00
36.16+	36.89	3.74	6.09		0.00
26.05	35.42+	0.00+	0.00		0.00
14.72	31.49	0.00	0.00		0.00
10.65	30.49	0.00	0.00		0.00
10.56	27.21	0.00	0.00		0.00
0.00	22.44	0.00			0.00
0.00	17.71	0.00			0.00
0.00	8.31	0.00			0.00
0.00	8.28	0.00			0.00
	8.10	0.00			0.00
	5.62	0.00			0.00
	0.00+	0.00			0.00
	0.00+				
	0.00				
	0.00				
	0.00				

* The number of personnel sampled during the BNCOC FTX scenario was much less than the others. Trainees were given smoke missions that day and were required to move to three different locations before smoke was generated. The sampling team followed the personnel, and could only contact twelve personnel to issue them the air sampling equipment.

+ Cadre exposures are designated with "+" after the values.

Soldiers in the O&M training scenario were exposed to significantly higher fog oil concentrations than those in he FTX scenario, namely 69.01 mg/m³-hour ±10.021 as compared to 8.70 mg/m³-hour ±1.265 ($F = 25.19$; $p = 0.0001$). While there were significant overall differences in fog oil concentrations among the three courses for each scenario, i.e., FTX and O&M ($F = 12.22$; $p = 0.0001$ and $F = 8.18$; $p = 0.0005$), there were no overall difference between students and cadre in fog oil exposures received during the O&M scenario (Table 6).

TABLE 6

Comparison of Differences in Fog Oil Smoke Exposure Concentrations between Students and Cadre during O&M

Course	Students			Cadre			F	p
	Mean	±SE	n	Mean	±SE	n		
54B10	128.1	32.78	23	92.1	25.10	5	0.25	0.6217
BNCOC	63.3	13.99	24	66.4	18.57	11	0.02	0.8986
COBC	19.8	5.51	25	39.4	14.75	6	2.16	0.1521

Level of Significance, $\alpha = 0.05$

No comparison can be made between the students and cadre in the FTX scenarios because the cadre were not exposed to fog oil smoke. Comparison of the means among courses by scenario and for the scenario total (exposure values of the specific scenario in all three courses) indicated that the highest fog oil concentrations were found in the 54B10AIT course. Results from the COBC and BNCOC/R courses were not significantly different from each other (Table 7).

TABLE 7

Mean Comparisons Among Courses for Personnel Fog Oil Exposure for Each Scenario (FTX and O&M) and for Scenario Total

Course	Scenario								
	Total			FTX			O&M		
	Mean* (mg/m^3-hr)	±SE	n	Mean* (mg/m^3-hr)	±SE	n	Mean* (mg/m^3-hr)	±SE	n
Total	44.13	6.350	160	8.70	1.265	66	69.01	10.021	94
54B10AIT	72.78[A]	16.360	52	15.74[C]	2.319	24	121.68[E]	27.260	28
BNCOC/R	49.53[B]	9.046	47	6.43[D]	2.542	12	64.30[F]	11.081	35
COBC	15.55[B]	3.511	61	3.97[D]	1.138	30	26.75[F]	6.228	31

* Scheffe multiple comparison procedure. (Means followed by the same letter are not different.)

Furthermore, fog oil concentrations measured during each course showed that these concentrations were significantly higher in O&M than in FTX scenarios (F-test; $p \leq 0.0041$).

The 54B10 AIT O&M scenario had significantly higher fog oil smoke concentrations than any of the FTX scenarios in all three courses. The 54B10 AIT O&M also had significantly higher fog oil smoke concentrations than that of the COBC O&M. Even though there was no statistical difference between the fog oil smoke concentrations in O&M, 54B10AIT and in O&M, BNCOC/R, there was a tendency for the smoke concentration to be higher in the 54B10AIT (Table 8).

TABLE 8

Mean Comparisons Among Scenarios/Courses for Personnel Exposure to Fog Oil Smoke for Each Scenario-Course Combination

Scenario Course Comb.	Mean* (mg/m^3-hr)	±SE	n
O&M, 54B10AIT	121.68 [A]	27.260	28
O&M, BNCOC/R	64.30 [A,B]	11.081	35
O&M, COBC	26.75 [B]	6.228	31
FTX, 54B10AIT	15.74 [B]	2.319	24
FTX, BNCOC/R	6.43 [B]	2.542	12
FTX, COBC	3.97 [B]	1.138	30

* Scheffe multiple comparison procedure. (Means followed by the same letter are not different.)

Soldiers in each scenario-course combination received as much or more fog oil smoke concentrations in 1 hour, than the 8-hour TLV time-weighted average of 5 mg/m^3 for oil mist (The American Conference of Governmental Industrial Hygienists, Inc. (ACGIH), 1988) (one-tailed Student's t-test; $p > 0.10$).

There was no statistically significant difference between the general area fog oil concentrations found in either the O&M scenario or the FTX scenario, 55.80 mg/m^3-hour ±20.079 versus 33.90 mg/m^3-hour ±17.103, respectively ($F = 0.67$; $p = 0.4255$) (Table 9).

TABLE 9

Mean Comparisons Among Courses for General Area Fog Oil Exposure for Each Scenario (FTX and O&M) and for Scenario Total

Course	Scenario								
	Total			FTX			O&M		
	Mean* (mg/m^3-hr)	±SE	n	Mean* (mg/m^3-hr)	±SE	n	Mean* (mg/m^3-hr)	±SE	n
Total	45.49	13.207	17	33.90	17.103	8	55.80	20.079	9
54B10AIT	105.64[A]	26.389	5	107.92[A]	19.193	2	104.12[A]	46.856	3
BNCOC/R	31.35[B]	14.228	6	12.10[B]	11.132	3	50.60[A]	22.753	3
COBC	9.52[B]	3.617	6	6.36[B]	6.358	3	12.69[A]	3.868	3

* Scheffe multiple comparison procedure. (Means in each column followed by the same letter are not different.)

While there were no significant overall differences in general area fog oil concentrations among the three courses in the O&M scenario ($F = 2.32$; $p = 0.1793$), the concentrations appear to be patterned after those in the FTX scenario (Table 9). The reported high general area fog oil concentration for the O&M scenario in the 54B10AIT course conforms with that of the FTX scenario in the 54B10AIT course ($F = 0.0$; $p = 0.9551$). There also were no differences between fog oil concentrations within either of the other courses for FTX or O&M scenarios (F-test; $p \geq 0.2032$).

Even though the 54B10AIT course for each scenario appears to have higher general area concentrations than the other two courses, comparisons among the scenario-course means show no statistical differences. The small sample sizes coupled with large standard deviations (SD) about these means preclude the finding of statistical significance (Table 10).

TABLE 10

Mean Comparisons Among Scenarios/Courses for General Area Exposure to Fog Oil Smoke for Each Scenario-Course Combination

Test	Mean* (mg/m^3-hr)	±SE	n
O&M, 54B10AIT	104.12 [A]	46.856	3
O&M, BNCOC/R	50.60 [A]	22.753	3
O&M, COBC	12.69 [A]	3.868	3
FTX, 54B10AIT	107.92 [A]	19.193	2
FTX, BNCOC/R	12.10 [A]	11.132	3
FTX, COBC	6.36 [A]	6.357	3

* Scheffe multiple comparison procedure. (Means followed by the same letter are not different.)

Exposures to Zn in HC smoke for the three cadre during the E&I demonstration were at 0.0375, 0.0652, and 0.0776 mg/m^3, the computed 8-hour time-weighted averages (Table 12, page 36). Cadre were exposed to HC smoke, but they were exposed to levels much lower than the threshold limit value of 1 mg/m^3. Students were evacuated from the area as soon as the HC smoke pots were ignited, and therefore were not exposed.

5.0 DISCUSSION

Exposure data presented in the results above identified and compared the degrees of exposure during the six fog oil smoke training situations and one HC smoke training situation. Higher fog oil smoke exposures can be expected in the O&M training scenario. The 54B10 students received higher exposure to fog oil than the students in both BNCOC/R and COBC. Based on our observations and the sampling results, excessive exposure to HC smoke to trainees and cadre is not expected. Our general observations of the training activities indicated that the training activities and how they are set up may have some impact on the extent of the soldiers' exposures to fog oil and HC smokes at the USACMLSCH.

5.1 Fog Oil Exposure Standard

Military training environments often present exposure conditions uniquely different from industrial work place activities. Additionally, exposure standards are not well defined for military materials such as fog oil smoke. Standard practice for evaluating the extent of personnel exposure is to quantify the concentration levels and compare them with an established standard. In the absence of an occupational exposure standard, a standard of a substance similar to fog oil can be used as a point of reference for exposure evaluation.

Fog oil and mineral oil are similar in chemical compositions, and perhaps in toxic effects (Liss-Suter et al., 1978). Hence, the exposure limit for mineral oil mist may be applied to establish safe levels for fog oil exposure. Despite the similarity, this assumption must be qualified with an understanding of the subtle differences between fog oil and mineral oil. A basic difference is in the particle-size distribution between fog oil smoke and oil mists. Mists are liquid-particle aerosols formed by condensation or atomization, with particle diameters generally in the range of submicrometer to about 20 μm (Hinds, 1982). Mineral oil mist is defined as airborne mist of petroleum-base cutting oils or white, mineral petroleum oil used in industry, with a TLV of 5 mg per cubic meter (mg/m^3). This TLV applies only to the liquid phase (ACGIH, 1986). Fog oil smoke aerosols are predominantly condensation particles with particle diameters ranging roughly from submicron to less than 5 μm. The fog oil composition has been characterized by Katz et al. (1980) in their report entitled "Physical and Chemical Characterization of Military Smokes." Fog oil consists almost of pure hydrocarbons, predominantly in the form of mixtures of aliphatic and aromatic components in relatively equal amounts with traces of alcohols, organic acids, esters, and organic nitrogen derivatives. Aliphatic hydrocarbons were in the C_{12}-C_{22} range and aromatics consisted of one through four-member rings. Compositions of mineral oil vary, and the oil may contain certain additives for specific purposes. The ACGIH has established a TLV for mineral oil mist at 5 mg/m^3.

5.2 Fog Oil Exposures

Soldiers were potentially exposed to fog oil smoke concentrations in excess of the ACGIH recommended TLV (5 mg/m³) for mineral oil mist during 1 hour of O&M training. The O&M training lasted 4 hours each day for 2 days.

The comparison of fog oil smoke exposures, during the O&M, experienced by the students and the cadre revealed no difference between the two populations. Both cadre and students were exposed to fog oil smoke concentration levels in excess to the TLV for mineral oil mist. While the students were exposed to smoke at exceedingly high concentration levels on a one time basis during the course, i.e., 8 hours of O&M in two days, and intermittently during the FTX, the cadre were exposed to equally high concentration levels continually for a three- or four-year on-station assignment, in their training activities during the O&M. This raises a concern because of the greater risk on the cadre due to the frequency of smoke exposures.

We believe that the potential overexposure may be attributable to work practices/habits in the training activities performed by both the students and the cadre. In most cases, the training mission dictates work activities. Changes in work habits without affecting the training mission are possible and could significantly reduce smoke exposures. Both the students and cadre were observed to habitually stay by the side of their generators, close to the source of smoke, possibly longer than was necessary. Students who were not directly involved in operating the generators were staying close to the generators where they were cleaning spare parts or the oil intake screens.

Based on our field observations and subjective interpretations, soldiers were exposed to higher concentration levels of fog oil smoke during the O&M scenario. First, unlike the FTX, constant attention was required of the students to maintain the smoke generators in operation. This forced the students to stay close to their generators. Cadre inspecting the generators or demonstrating maintenance procedures to the students also stayed close to the generators. Second, many generators had to be used to afford all students the required "hands-on" training during the O&M. During our field sampling, as many as 32 generators were placed in a single line at the training range. Generators were placed from 4 to 10 feet apart. Smoke appeared to diffuse laterally, within a radius of 5 to 8 feet from the point of generation, before the wind took effect on the smoke. Smoke from one generator could overlap the adjacent generators. When a student knelt next to his generator, he was exposed not only to smoke from his own generator, but also to the smoke from adjacent generators. Therefore, the much higher exposure levels experienced by soldiers involved in O&M possibly could have been attributed to smoke generated from as many as three generators.

We recognize that certain desired obscuration effects or smoke densities are controlled by varying the distances between generators. In the case of the O&M, the primary objective was to allow the students to practice hands-on maintenance and operation of the generators. Therefore, obtaining desired obscuration effects may not be as important. We believe that the generators could be set physically farther apart during O&M training.

During the FTX training, the students had to start the generators and perform minor adjustments to optimize the smoke operations. In most cases, once the generator started to produce smoke, the students moved away from their generators until resupply of fog oil or further adjustments on the generators were needed. The exposure levels measured during the FTX training scenarios constituted exposure resulting from the start of the generator, initial adjustments, re-supply of fog oil, and shutdown of the generators. Soldiers spent less time in smoke during the FTX, and less exposure would be expected. Unlike the O&M training, large areas were used for the FTX. Hence, generators mounted on jeeps were located at least 20 feet apart.

Originally, we had thought that the number of generators used during a training scenario would influence the degree of personnel exposure (schematic diagrams depicting the locations of the generators and personnel are included in Appendix A). Based on the sample results, the total number of generators used does not appear to have affected the personal exposure to smoke. The generators normally were placed along a line perpendicular to the estimated direction of the wind. Unless the wind directions shifted, personal exposure most likely would result from smoke produced, at a maximum, from three generators as discussed earlier. If the generator line had been set along the path of the wind direction, the total number of generators might indeed have affected the personnel exposures. In any case, there is no simple way to estimate the proportionality between the total number of generators used and the extent of personal exposure. Test results would most likely depend on the existing atmospheric stability and wind speed. Table 11, page 36, shows the number of generators used in the sampled training scenarios and courses.

The median age of the 54B10 trainees who participated in this field study was 19, much younger than those students in the COBC and the BNCOC/R courses. Based on our observations, these younger soldiers underwent more rigorous training than older soldiers in the COBC or the BNCOC/R courses, particularly during O&M. The rigorous training may have been based on more stringent training requirements or learning objectives. In this case, higher personal exposure levels may have been inevitable. One may conjecture that the more stringent training requirements/learning objectives in the training, the higher concentration levels of the exposure to fog oil smoke.

Results from general area sampling consistently demonstrated that the predominant particle sizes of fog oil smoke fall between 1 and 3 μm in MMAD. Other particle sizes, either greater or smaller than the stated MMAD, were not detected. Particles with MMAD between 1 and 5 μm tend to have maximum retention in the alveolar regions of the lung. This is true of fog oil smoke.

The effects of fog oil particles on humans is uncertain. However, inhalation studies of fog oil smokes in animals have indicated that these smokes can result in pulmonary changes. Chemical pneumonia and inflammatory processes with progressive granulomas have been observed. Reports of the effects on humans exposed to similar petroleum distillate fractions have varied. Aspiration of mineral oils can cause chemical pneumonia. While some workplace investigations have indicated no effects from chronic exposure to mineral oils and related compounds, paraffinomas (chronic granulomas) and diffuse and focal pneumonitis have been observed in persons repeatedly exposed to mineral oils. Individuals such as the cadre may be of particular concern because of their regular inhalation exposure to fog oil smoke over extended periods of time.

5.3 HC Smoke Exposure Standard

Katz, et al. (1980) conducted a study to characterize the physical and chemical compositions of HC smoke and found it consisted predominantly of $ZnCl_2$. Hence, field sampling for HC smoke exposure specifically was designed to collect $ZnCl_2$, and the samples were quantitatively analyzed for zinc ion concentration. The evaluation of soldiers' exposure to HC smoke, therefore, is based on the TLV of 1 mg/m^3 for $ZnCl_2$ recommended by the ACGIH. The potential health hazards from exposure to $ZnCl_2$ in HC smoke was studied (Hill et al., 1978). Zinc chloride is hygroscopic and stringent. Persons breathing in high concentrations will suffer from pulmonary irritation. Extended exposure can be fatal. Hill et al. (1978) cited cases in which workers' exposure to $ZnCl_2$ in the eyes and nose resulted in burns on the eyes, permanently impaired vision, and permanent loss of sense of smell.

5.4 HC Smoke Exposure

The 54B10 students were not exposed to HC smoke. We recall from our observations that 54B10 students were taught the importance of masking in HC smoke. Notes from our observations pertaining to masking are attached in Appendix B. However, cadre did not carry masks. During the classroom session on E&I demonstration, cadre were exposed briefly to HC smoke; but the concentration levels did not exceed the TLV for $ZnCl_2$ (Table 11).

Particle-size distribution sampling results indicated that the MMAD is in the range of 0.4 to 2.8 μm. These values are consistent with results previously reported (DeVaull, 1989), and the particles are considered to have a high potential for retention in the alveolar region of the lung.

6.0 CONCLUSION

Soldiers are exposed to potentially excessive levels of fog oil smoke during training exercises at the USACMLSCH, based on the ACGIH recommended TLV of 5 mg/m^3 for mineral oil mists. Over-exposure can be minimized by modifying work/training habits of the cadre and the trainees, and by locating the smoke generators farther apart.

Soldiers involved in the employ and ignite (E&I) demonstration did not receive exposure to $ZnCl_2$ from HC smoke in quantities greater than the ACGIH recommended TLV for $ZnCl_2$ at 1 mg/m^3.

7.0 RECOMMENDATIONS

The cadre and the students should be advised that, in all six training situations, exposure to fog oil smoke is likely to reach concentrations significantly higher than the TLV established for mineral oil mist, a material similar to fog oil.

While there is no difference in the magnitude of exposures to fog oil smoke between the students and the cadre during the O&M, the cadre exposure is of a greater concern because of the frequency and the duration of exposure over the entire period of the cadre military assignment at the USACMLSCH. The cadre need to be aware of the potential for overexposure to fog oil smoke and be encouraged to exercise persistent caution in the conduct of training to avoid situations leading to overexposures.

Some changes in work habits should be made to minimize the exposure to fog oil smoke. Students and cadre should refrain from staying between generators. If the students have to stay close to the generators, they should locate themselves, as much as they possibly can, behind the generator and upwind of the smoke plume. Personnel cleaning the generator spare parts and not involved directly with the generators, should do the cleaning away from smoke.

Because smoke spreads laterally at the point of generation, particularly during O&M training, generators should be placed farther apart to reduce personnel exposure to smoke. We recommend a minimum distance of 20 feet between generators.

The USACMLSCH should continue to teach trainees the importance of respiratory protection against smoke, particularly in HC smoke. For protection against HC smoke, the use of a standard issue protective mask is important regardless of the exposure concentrations.

8.0 REFERENCES CITED

American Conference of Governmental Industrial Hygienists, Inc. (ACGIH). 1988. Threshold Limit Values and Biological Exposure Indices for 1988-1989, Cincinnati, Ohio.

American Conference of Governmental Industrial Hygienists, Inc. (ACGIH). 1986. Documentation of the Threshold Limit Values and Biological Exposure Indices, Cincinnati, Ohio.

Department of Health, Education, and Welfare. 1984. HEW-NIOSH Publication No. 84-100, NIOSH Manual of Analytical Methods, Third Edition.

DeVaull, G., W.E. Dunn, J.C. Liljegren, and A.J. Policastro. 1989. Analysis Methods and Results of Hexachloroethane Smoke Dispersion Experiments Conducted as Part of Atterbury-87 Field Studies (Draft), Argonne National Laboratory, USAMRDC Project Order No. 84PP4822.

Hill, H.G., K. Wasti, and J.E. Villaume. 1978. Occupational Health and Safety and Environmental Aspects of Zinc Chloride, The Franklin Institute Research Laboratories, USAMRDC Contract No. DAMD-17-77-C-7020, AD A056020.

Hinds, W.C. 1982. Aerosol Technology, Wiley-Interscience, New York.

Katz, S., A. Snelson, R. Butler, R. Farlow, R. Welker, and S. Mainer. 1980. Physical and Chemical Characterization of Military Smokes - Part II, Illinois Institute of Technology Research Institute, USAMRDC Contract No. DAMD-17-77-C-7020, AD A093205.

Liljegren, J., W. Dunn, G. DeVaull, D. Thoman, and A. Policastro. 1986a. Analytical Procedures for Field Study of Fog Oil Smokes (Draft), Argonne National Laboratory, USAMRDC Project Order No. 84PP4822.

Liljegren, J., W. Dunn, and G. DeVaull. 1986b. Field Study of Fog Oil Smokes, Argonne National Laboratory, USAMRDC Project Order No. 84PP4822, AD A205334.

Liss-Suter, D., J. Villaume, and F. Goldstein. 1978. Occupational Health and Safety Aspects of the Fog Oils SGF No. 1 and SGF No. 2 and Smoke Screens Generated From Them, The Franklin Institute Research Laboratories, USAMRDC Contract No. DAMD-17-77-C-7020, AD A055903.

Menichini, E. 1986a. Sampling and Analytical Methods for Determining Oil Mist Concentrations, Instituto Superiore di Sanita, Viale Regina Elena, 299, 00161 Roma, Italy, Ann. Occup. Hyg. 30[3]: 335-348.

Menichini, E. 1986b. Particle Size Distribution of Oil Mist in the Workplace, Instituto Superiore di Sanita, Viale Regina Elena, 299, 00161 Roma, Italy, Ann. Occup. Hyg. 30[3]: 349-363.

Policastro, A. and W. Dunn. 1985. Survey and Evaluation of Field Data Suitable for Smoke Hazard Model Evaluation, Argonne National Laboratory, USAMRDC Project Order No. 84PP4822, AD A161880.

Rosencrance, A., S. Hoke, and K. Kamrud. 1988. Determination of Fog Oil in Air Samples by Gas Chromatography, Technical Report No. 8805 (Draft), USABRDL, Fort Detrick, Frederick, MD 21701-5010.

SAS[R] Institute. 1985. SAS User's Guide: statistics, 5th Edition. SAS Institute, Cary, NC.

Smart, D.A. 1989. Smoke Exposure Assessment Research Master Plan (Draft), USABRDL, Fort Detrick, Frederick, MD 21701-5010.

Supelco. 1987. GC Bulletin 849, Thermal Desorption for Monitoring Hazardous Airborne Hydrocarbons (available from Supelco, Inc., Bellefonte, PA 16823-0048).

TABLE 1
Percent Recovery of Fog Oil from Glass Slides
in Tins and Glass Fiber Filters

	Glass Slides in Tins percent Recovery (±SD)		Glass Fiber Filters percent Recovery (±SD)	
	Concentration		Concentration	
Time	Low	High	Low	High
Immediate	89.6 (9.6)	96.8 (1.4)	97.6 (7.4)	97.6 (1.3)
3 months	105.1 (5.3)	104.2 (1.7)	95.6 (7.7)	98.9 (2.8)
6 months	96.7 (5.3)	90.5 (1.9)	96.0 (3.7)	93.0 (3.3)
Average	97.1 (7.8)	97.2 (6.8)	96.4 (1.1)	96.5 (3.1)

TABLE 2

A Summary of Gas Chromatograph Instrument Conditions
for Analysis of Fog Oil Smoke Aerosol

Instrument	Hewlett-Packard Model 5890 Gas Chromatograph (Hewlett-Packard Co., Avondale, PA)
Detector	Flame Ionization
Column	5 meter, 0.53 mm i.d. methyl silicone
	Temperatures
Injection Port	250°C
Detector	300°C
Column	
Initial	190°C, 1 min hold
Rate	35°C/min
Final	300°C, 2 min hold
Carrier Gas	Helium, zero grade
Flow Rate	25 mL/min
Analysis Time	6.5 min

TABLE 3

A Summary of Instrument Conditions for Zinc Analysis

INSTRUMENT	Perkin Elmer Model 3030 Atomic Absorption Spectrophotometer (Perkin Elmer Corp., Norwalk, CT)
LAMP	Hollow Cathode Lamp (Perkin Elmer Corp.)
WAVELENGTH	213.9 nm
SLIT WIDTH	0.7 nm
FLAME	Air/acetylene flame, lean blue.

TABLE 4

Percent Recovery of Zinc from Metal Containers

LOW LEVEL			
DATE	AMOUNT ADDED (mg/L)	AMOUNT RECOVERED (mg/L)	PERCENT RECOVERY
9-28-87	1.000	0.978	97.80
9-30-87	1.000	1.006	100.60
HIGH LEVEL			
9-28-87	10.000	9.560	95.60
9-28-87	10.000	9.980	99.80
9-28-87	10.000	9.800	98.00

TABLE 11

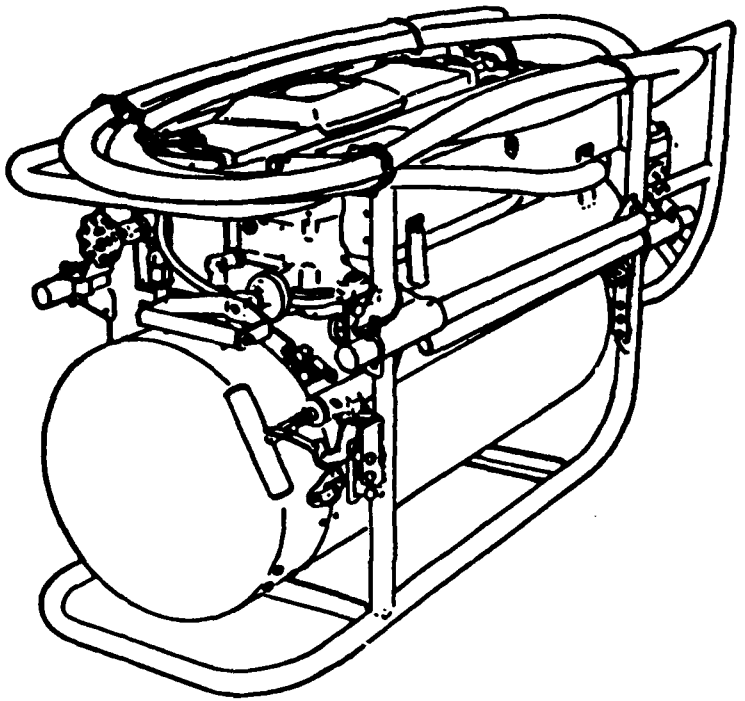
Numbers of Fog Oil Smoke Generators Used in Training

Scenario	Course	Number of Generators Used
O&M	54B10AIT	32
	BNCOC/R	13
	COBC	20
FTX	54B10AIT	30
	BNCOC/R	18
	COBC	16

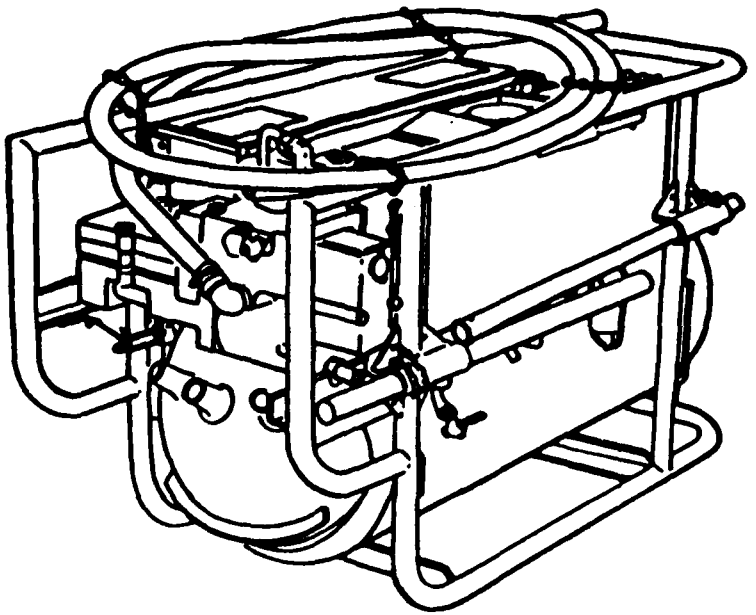
TABLE 12

Sample Results on Cadre Exposure to Zinc Chloride in HC Smoke

Instructor	$ZnCl_2$ Conc. in mg/m^3	Duration of Exposure in minutes	8-hr Time-weighted Average, mg/m^3
1	1.74	18	0.0652
2	2.07	18	0.0776
3	1.00	18	0.0375



FRONT COVER END



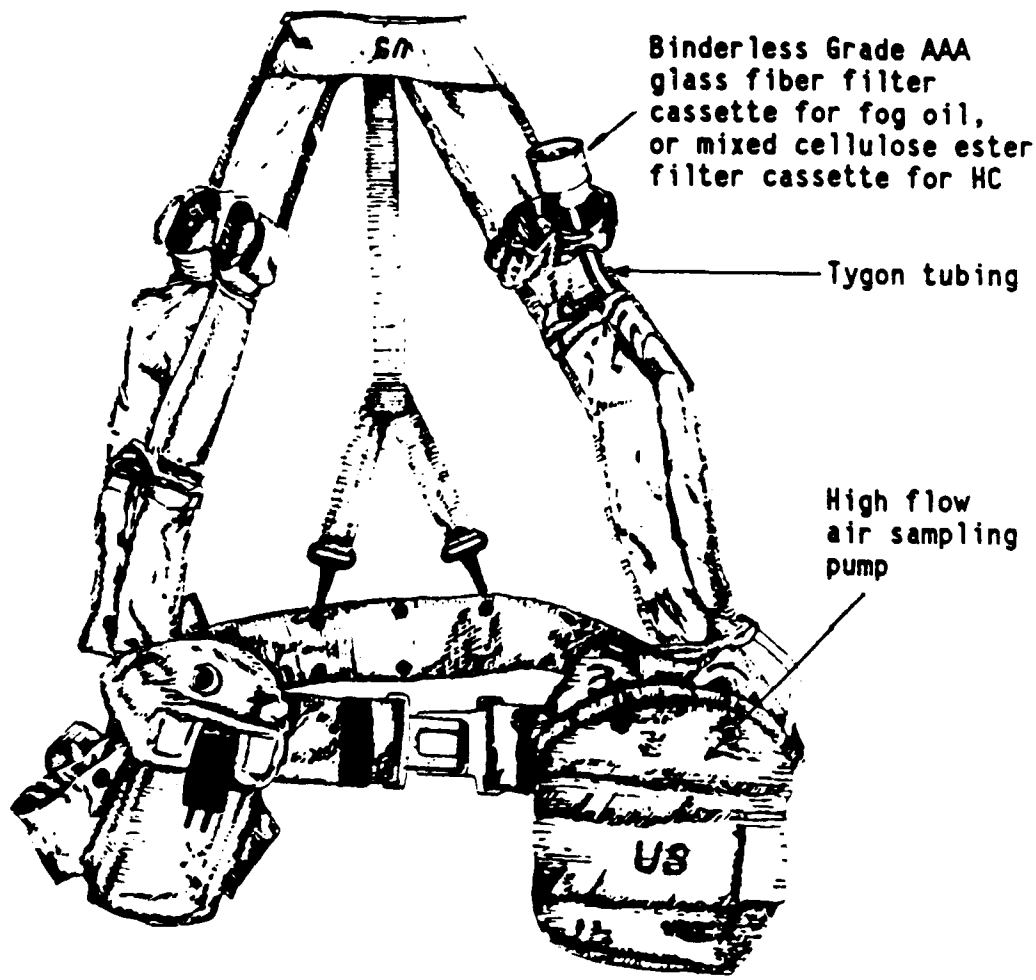
SMOKE DISCHARGE END

FULL EXTERNAL VIEW OF M3A4 PULSE JET MECHANICAL SMOKE GENERATOR

FIGURE 1

Figure 2.

Modified Load-Carrying-Equipment with Breathing-Zone Sampling Equipment



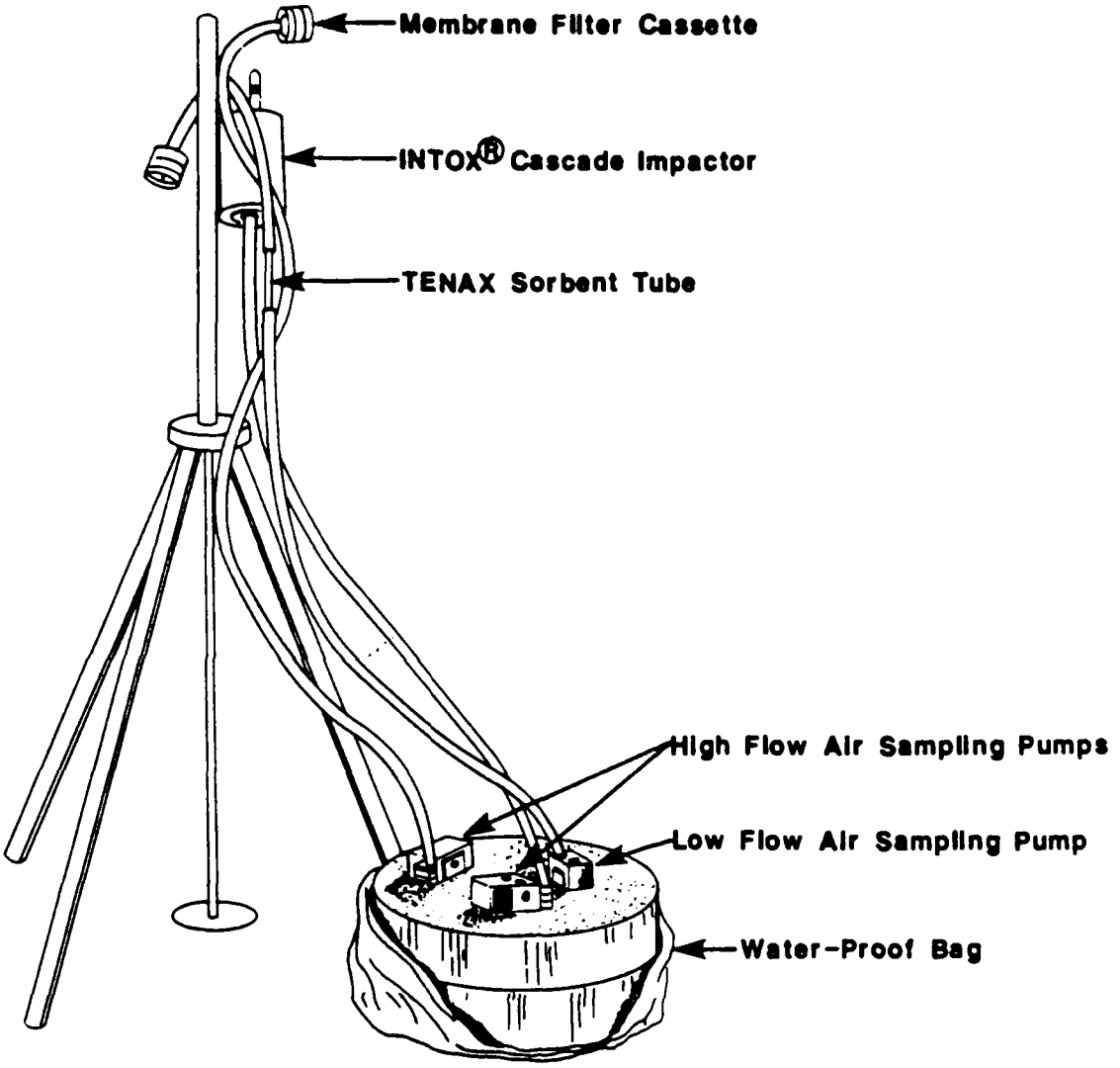


FIGURE 3

General Area Sampling Stand

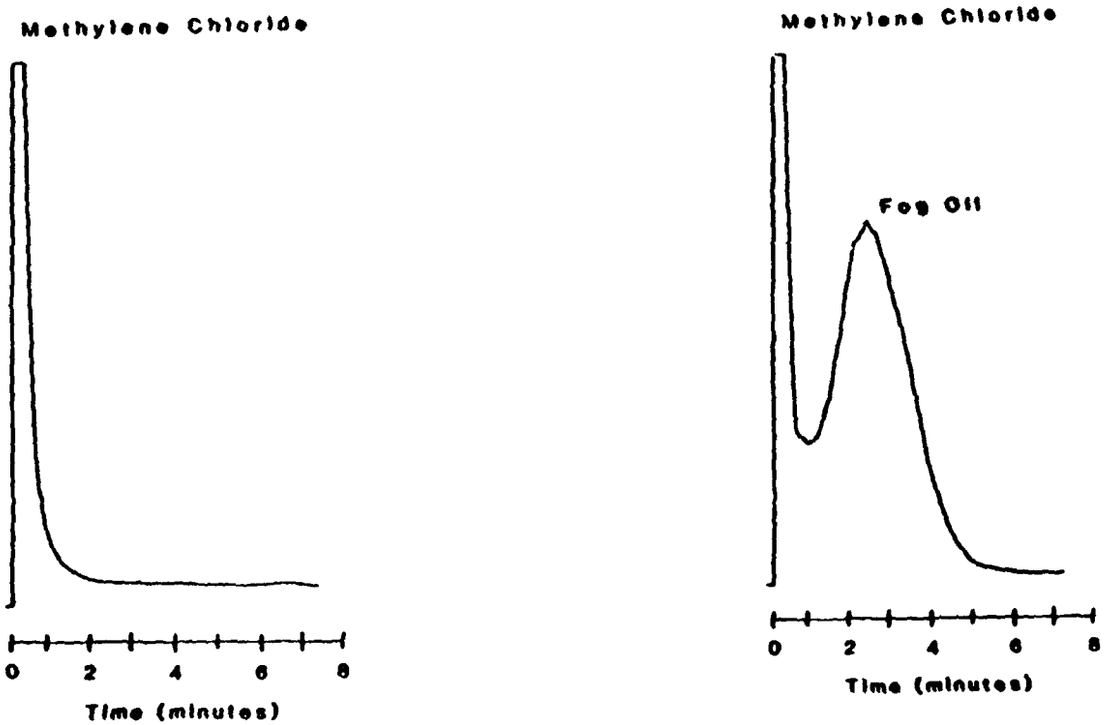


FIGURE 4. Gas Chromatogram of Fog Oil on a 5 meter 0.53 mm Methyl Silicone Column using FID.

Appendix A

Schematic Diagrams of Locations of Personnel Sampling and General Area Sampling

	Page
54B10 "Operate & Maintain" Training.....	42
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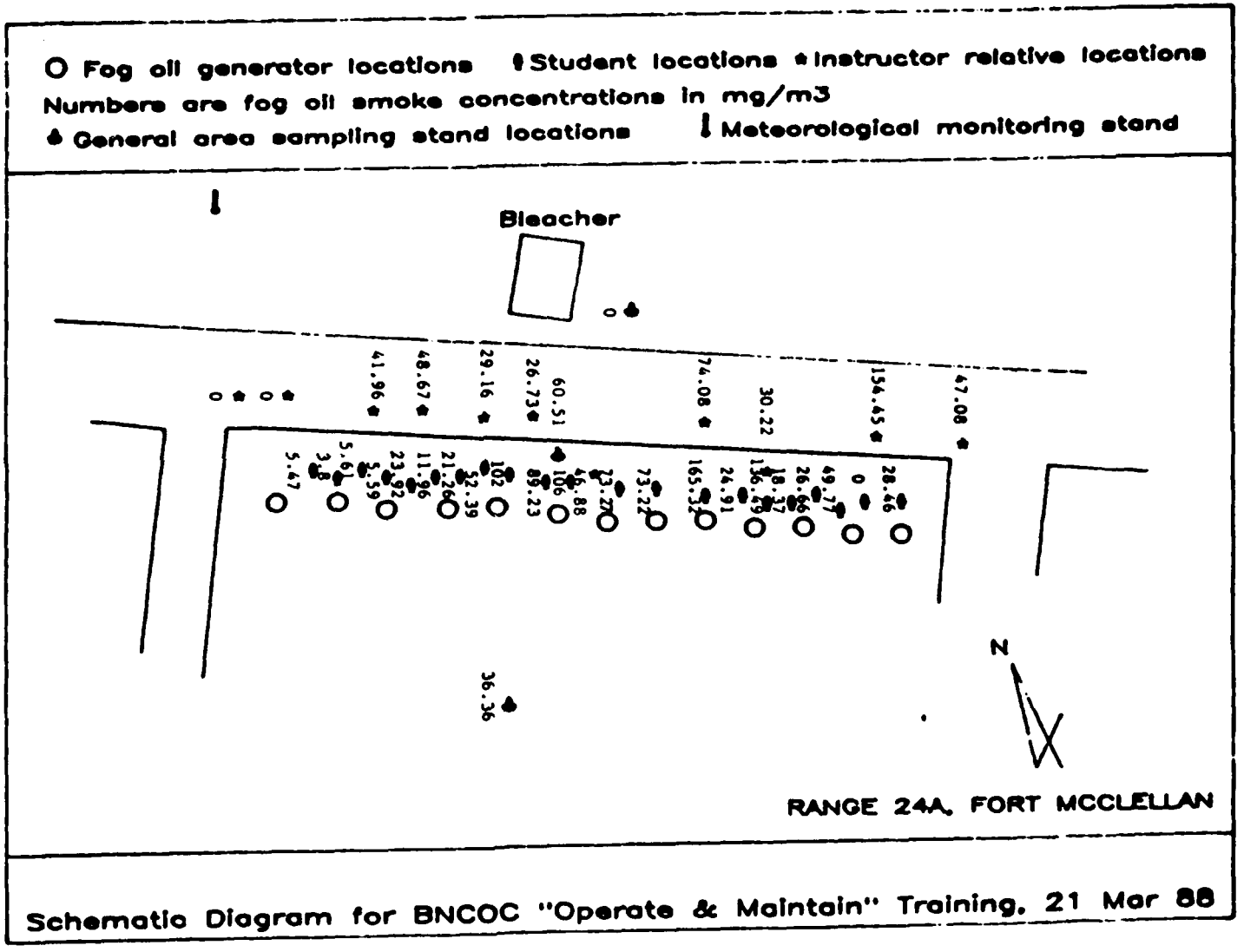
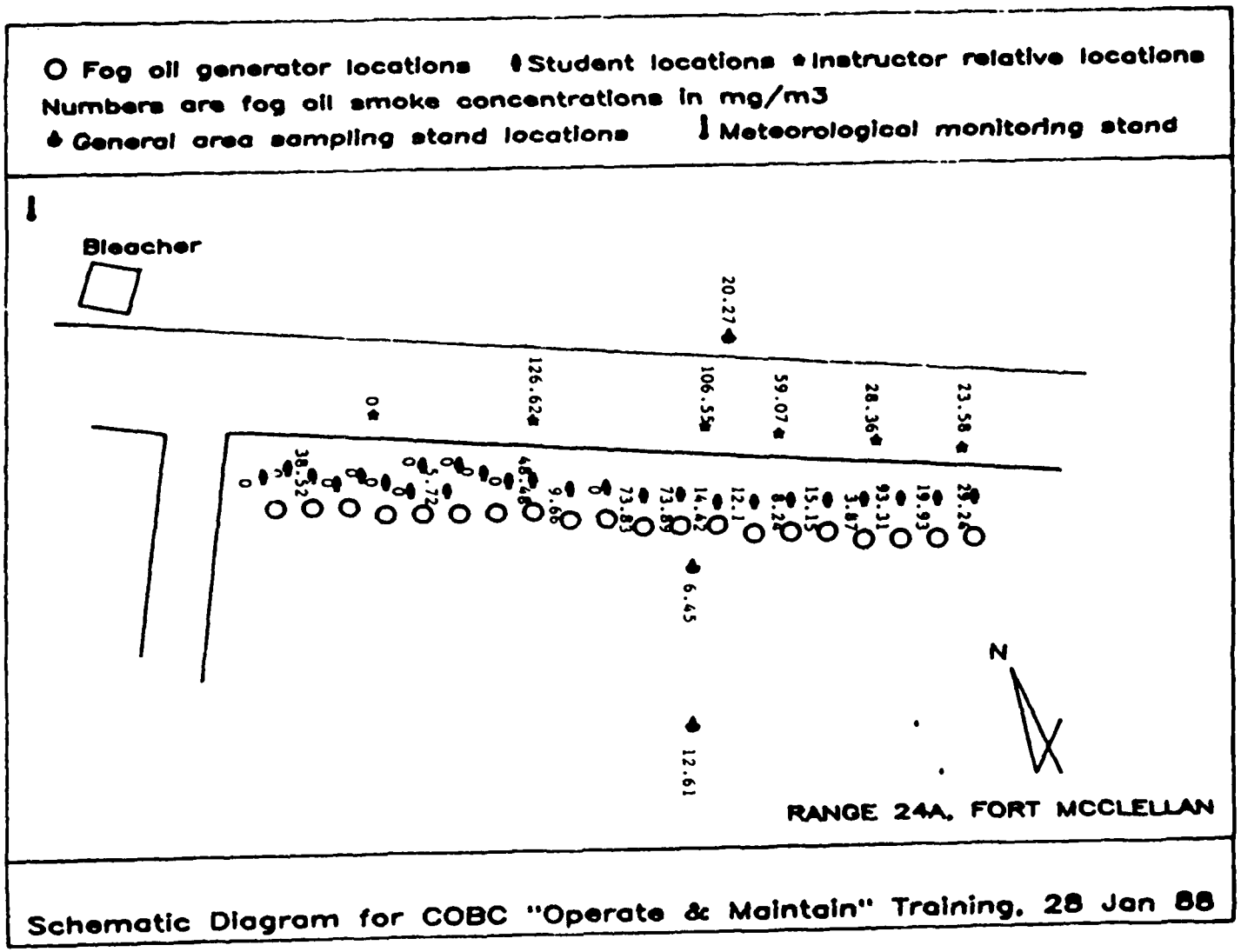
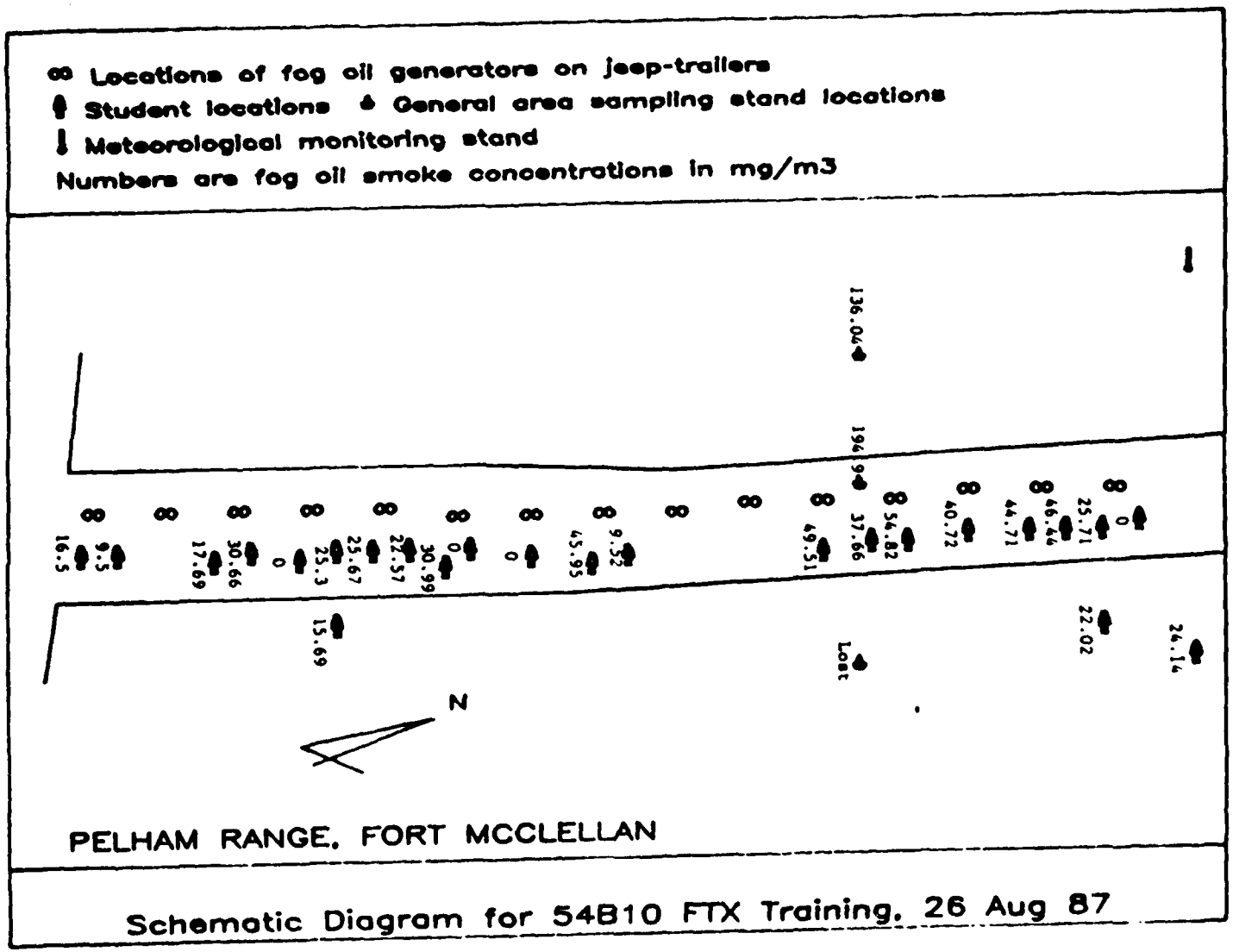
O Fog oil generator locations ♦ Student locations ♦ Instructor relative locations
Numbers are fog oil smoke concentrations in mg/m3
♦ General area sampling stand locations ▌ Meteorological monitoring stand
Schematic Diagram for 54B10 "Operate & Maintain" Training. 4 Sep 87
RANGE 24A, FORT MCCLELLAN
N
Bleacher
24.43
72.43
67.43
17.59
30.9
9.94
25.68
35.78
126.12
148.19
156.39
213.12
190.27
120.83
0
87.2
459.47
73.11
112.38
77.41
8.65
63.3
58.46
119.41
0
125.54
2.14
7.19
41.42

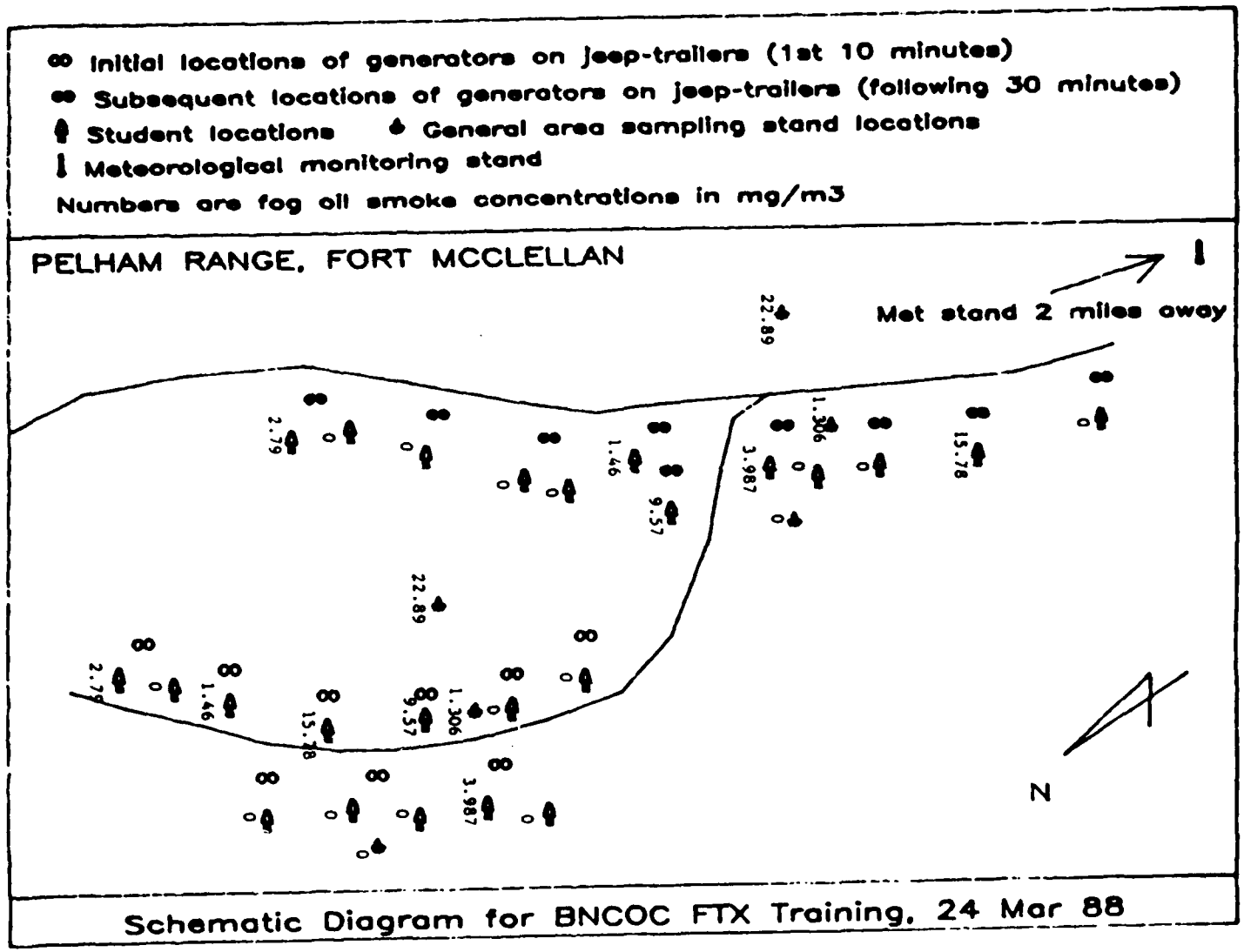


Schematic Diagram for BNCOC "Operate & Maintain" Training, 21 Mar 88

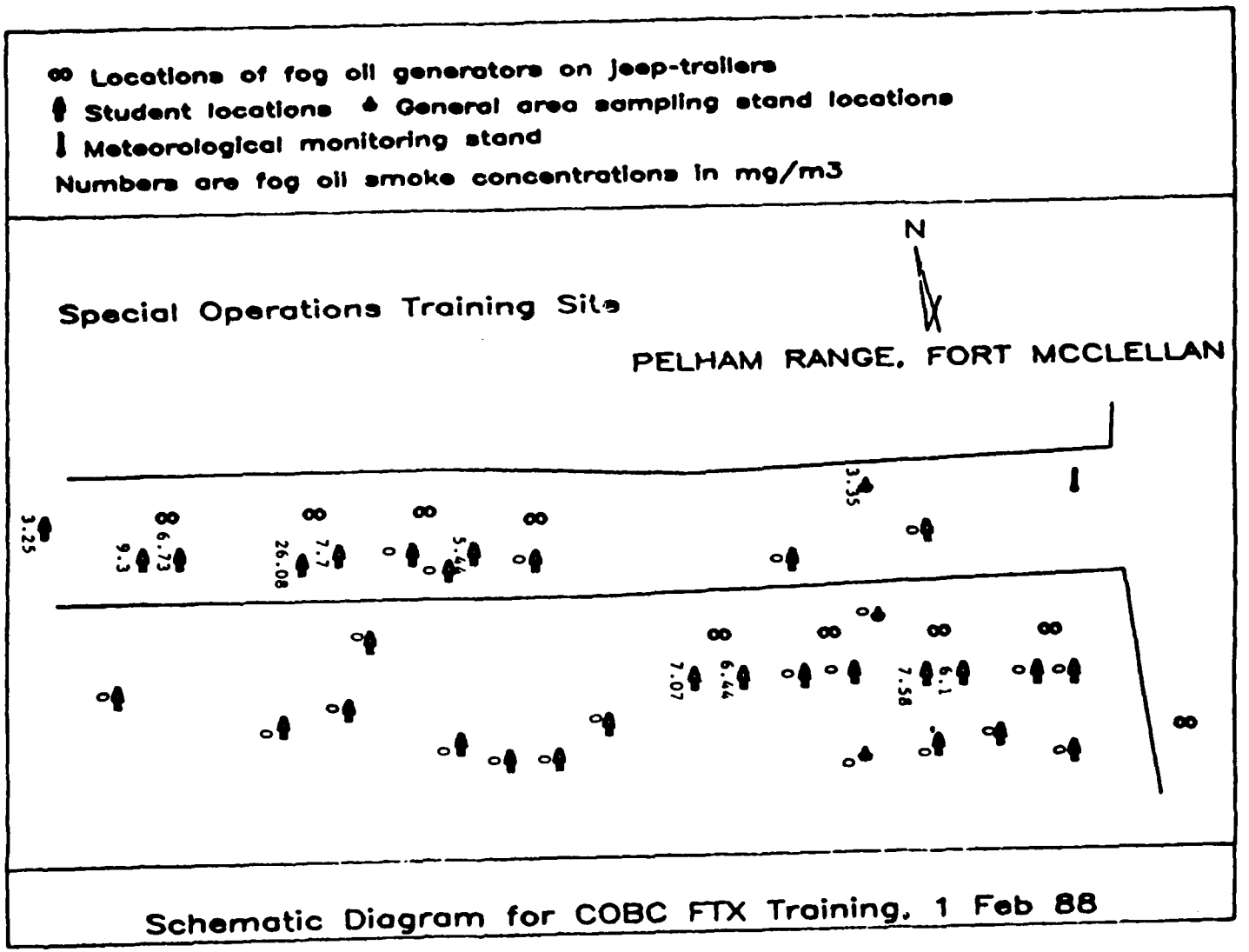


Schematic Diagram for COBC "Operate & Maintain" Training, 28 Jan 88


Locations of fog oil generators on jeep-trailers
Student locations
General area sampling stand locations
Meteorological monitoring stand
Numbers are fog oil smoke concentrations in mg/m3
136.04
194.9
37.66
49.51
54.82
40.72
44.71
46.44
25.71
0
9.52
45.95
0
30.99
22.57
25.67
25.3
0
30.66
17.69
9.5
16.5
15.69
Lost
22.02
24.14
N
PELHAM RANGE. FORT MCCLELLAN
Schematic Diagram for 54B10 FTX Training. 26 Aug 87



Schematic Diagram for BNCOC FTX Training, 24 Mar 88



Schematic Diagram for COBC FTX Training, 1 Feb 88

Appendix B

Use of Protective Mask During Training at the U.S. Army Chemical School

Field Exposure of Chemical School Students and Cadre to Fog Oil and Hexachloroethane Smokes

Use of Protective Mask During Training

1. **Purpose.** The purpose of this appendix is to summarize the authors' observations on soldiers' use of standard issue protective masks during training under this study. These observations were made when the soldiers were aware of our presence in the field, and the soldiers understood our position in regard to the medical requirement for masking in smoke. We do not know if the soldiers would have disregarded masking if we had not been present.

2. **Availability of Protective Masks.** Students carried the M17A1 Protective Mask to the field. During the O&M training, they left their LCE, including their masks, in the "formation" area. During the FTXs, trainees carried their protective masks in "NBC-ready" position or in their assigned vehicles. Cadre did not carry protective masks.

3. **Cadre's Emphasis on Masking in Smoke.** The cadre emphasized the need to mask in smokes, and particularly enforced masking during training in HC smoke. Both cadre and students believed that fog oil smoke was not very toxic and brief exposure to fog oil smoke without respiratory and skin protection was acceptable because it was unavoidable. Hence, masking was not enforced during training in fog oil smoke.

4. **Masking in HC Smoke.** Potential exposure to HC smoke can occur during the E&I demonstration training in the application/use of HC smoke pots. This occurred in two situations. First, an M5 smoke pot was ignited by a cadre member while the students were gathered on the bleachers and lectured by another cadre. When the smoke began to drift toward the bleachers, the cadre stopped the lecture and instructed the trainees to move out of the smoke cloud as they donned their masks. Second, students were involved in igniting the smoke pots in the training area. Trainees were instructed to don their protective masks and clear the trapped air inside the masks before igniting the M8 smoke pots. As soon as the smoke pots were ignited, trainees moved quickly away from the training area and observed the smoke from a safe distance. With the precautions to mask before igniting the smoke pots, trainee exposure to HC smoke was considered unlikely. Cadre were exposed to HC smoke during the lecture as they moved away from the smoke cloud.

5. **Masking in Fog Oil Smoke.** Cadre planned the locations of the fog oil smoke generators based on the weather report. Generally, the generators were located in a line perpendicular to the estimated wind direction; and the students were instructed to stay upwind of the generators at all times. Sometimes the students had to kneel close between generators to perform adjustments and maintenance.

a. During the O&M training, much exertion and movement around the generators were required. Inevitably, masking could present some cumbersome problems for the students. When the wind changed direction, some students continued to stay close to the generators until they could not see in smoke.

Then, they would stop and find their way out of the smoke without masking. Those students who were standing by would move out of the smoke immediately. Changes in wind direction occurred quite frequently during our study. Cadre did not have masks available, but they would continue to stay in the smoke until they could not see.

b. During the FTX, students had fewer problems with their generators. Once the generators began to produce smoke, most trainees moved away from the generators and stayed upwind to observe the operation while a few others stayed with their generators by their vehicles. Those staying with their generators donned their masks when they found themselves in smoke. Trainees who were observing at a distance usually did not carry their masks; and on several occasions, smoke drifted toward them when the winds changed direction. Cadre were evaluators of the exercise and had little or no involvement in the actual smoke operations. They stayed at a safe distance well away from the smoke to observe the trainees.

6. **Conclusion Based on Our Observations.** Respiratory protection during training in smoke is recognized and taught in the USACMLSCH. Based on their experience, cadre who have had worked with fog oil smoke for many years do not believe that fog oil smoke is sufficiently toxic to warrant masking. However, they do not discourage their students from wearing the mask in fog oil smoke. Cadre do insist that the students wear their masks during training in HC smoke. During the O&M training, no trainee wore the mask in fog oil smoke. During the FTX, less than half of those trainees working in fog oil smoke wore their masks.

ABBREVIATIONS, ACRONYMS, AND SYMBOLS

^{o}R	absolute temperature in Rankine; 460 + degrees Fahrenheit
AIT	advanced individual training
Al	aluminum
AL_2O_3	aluminum oxide
ACGIH	The American Conference of Governmental Industrial Hygienists, Inc.
ANOVA	analysis of variance
BNCOC/R	Basic Non-commissioned Officers' Course for Reclassified Non-commissioned Officers
C	carbon
COBC	Chemical Officers' Basic Course
E&I	employ and ignite
FTX	field training exercise
GC/FID	gas chromatograph/flame ionization detection
>	greater than
HC	hexachloroethane
C_2Cl_6	hexachloroethane
hr	hour(s)
<	less than
Lpm	liters of air volume per minute
LCE	load-carrying equipment, commonly called web gear
MMAD	mass median aerodynamic diameter
µm	micrometer
MOS	military occupational specialty
mg	milligram
mg/m^3	milligrams of contaminant per cubic meter of air
mg/L	milligram per liter
mL	milliliter
mm	millimeter
min	minute(s)
nm	nanometer
NCO	non-commissioned officer
O&M	O&M
ppm	parts per million
SD	standard deviation
SE	standard error
^{o}C	temperature reading in degrees Celsius
^{o}F	temperature reading in degrees Fahrenheit
TLV	threshold limit value established by the American Conference of Governmental Industrial Hygienists, Inc.
USABRDL	U.S. Army Biomedical Research and Development Laboratory
USACMLSCH	U.S. Army Chemical School
USAMRDC	U.S. Army Medical Research and Development Command
F-test	variance ratio test
Zn	zinc
$ZnCl_2$	zinc chloride
ZnO	zinc oxide

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